

Case 1 : Synthetic Jet into quiescent air. URANS Simulations with Eddy-Viscosity and Reynolds-Stress Models

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Content

- Case 1 computed with *Code_Saturne*
- Computational Domain
- Implementation and Case Specific Details
- Sensitivity Studies
- Solution Methodology

Code_Saturne

- RANS-equations or LES
- Finite volume solver on unstructured grids developed at EDF
- Using collocated arrangement for all the unknowns (Rhie and Chow interpolation, 1982)
- The flow is assumed incompressible and Newtonian and the density is constant

Code_Saturne

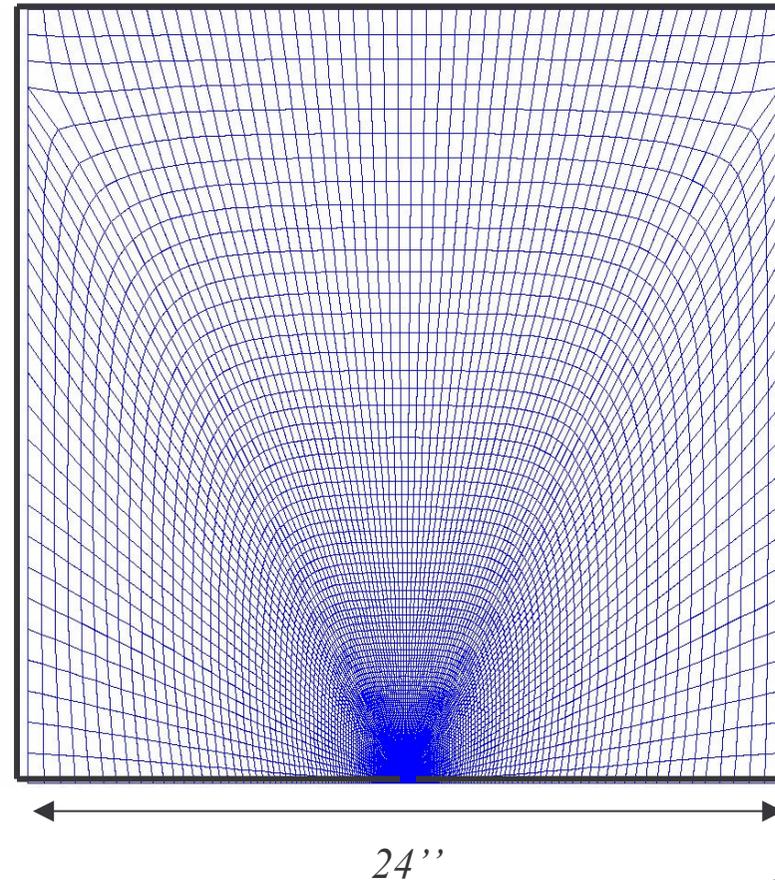
- Velocity and pressure coupling is ensured by a prediction/correction method with a SIMPLEC algorithm (Ferziger & Peric, 1999)
- The Poisson equation is solved with a conjugate gradient method
- Other linear systems are solved with a JACOBI algorithm

Turbulence Models

- Ability of *standard* turbulence models to close the phase-averaged Navier-Stokes equations
 - Eddy-viscosity Model : standard k - ε model
 - Reynolds Stress Model : Rotta+IP
 - Wall functions were used in both cases at all solid boundaries

Computational Domain

- 2D structured Mesh
- The extent of the domain is the same as the experimental box
 - ➔ to avoid undesired confinement effects
- The internal cavity is not modeled
 - ➔ unsteady boundary conditions are imposed at the slot exit



Implementation and Case Specific Details

- Boundary conditions :
 - Outlets (because of the flow incompressibility)
➔ to allow mass conservation at each time step

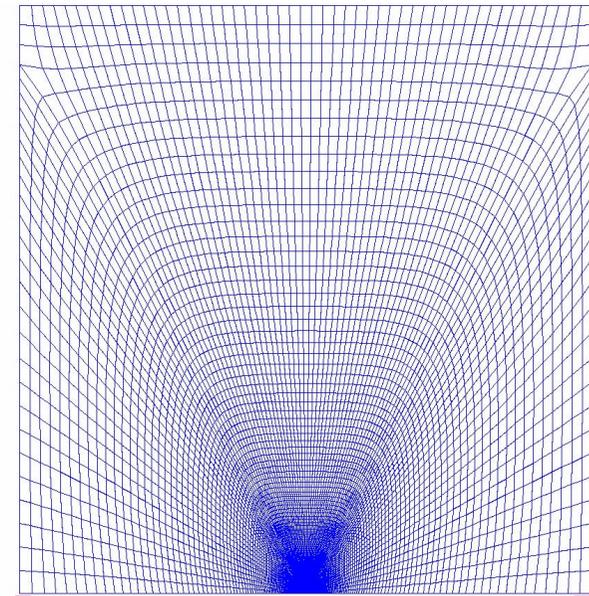
Two small outlets at the lower corners of the box.

When the jet is blowing, these regions correspond to standard outlet conditions.

During the aspiration phase of the cycle, fluid enters through the outlets and Dirichlet boundary conditions are imposed for scalars

- Initialisation

Computations are started from rest state with small values for turbulence quantities. The domain is initialized with low turbulence intensity $I=0.05\%$ and a dissipation rate giving a ratio $\nu_t/\nu=10$

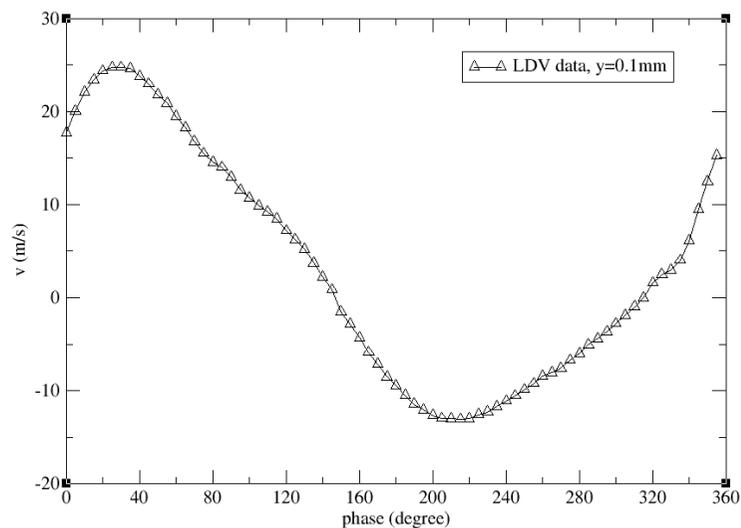


Outlet boundary conditions

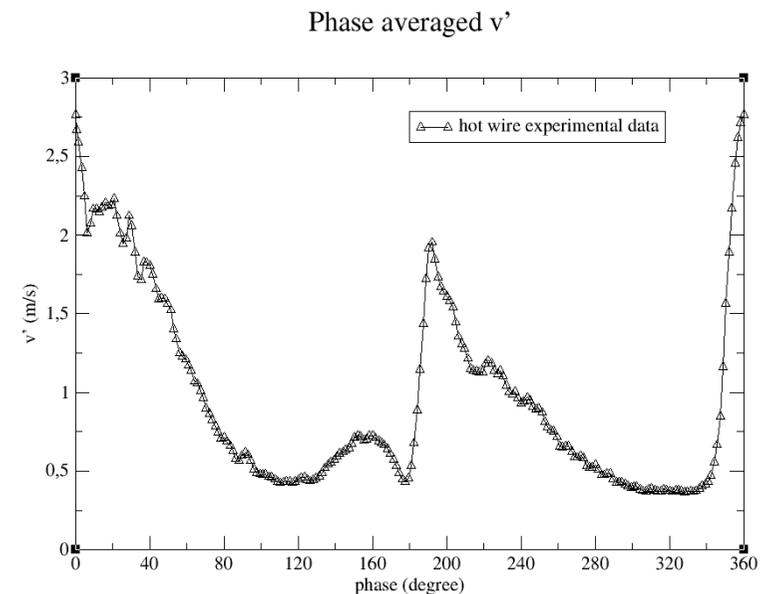
Implementation and Case Specific Details

- Boundary conditions
 - Solid walls : standard wall functions
 - Slot exit : unsteady Dirichlet boundary condition

v is taken from the LDV experimental data (at $y=0.1\text{mm}$). The velocity is taken uniform across the slot exit.



v' is taken from the hot wire experimental data (at $x=0, y=0, z=0$)



Sensitivity Studies

- Influence of the grid and time step :
 - 2 different grids
 - Cell size for the coarse grid :
 - 50 squared cells at the slot exit
 - Number of cells : 15707
 - For the fine grid, each cell has been divided in four cells, leading to 62828 cells.
 - Several time steps (0.5, 0.25, 0.125 degrees), where the value in degree corresponds to $\Delta\phi=360f\Delta t$

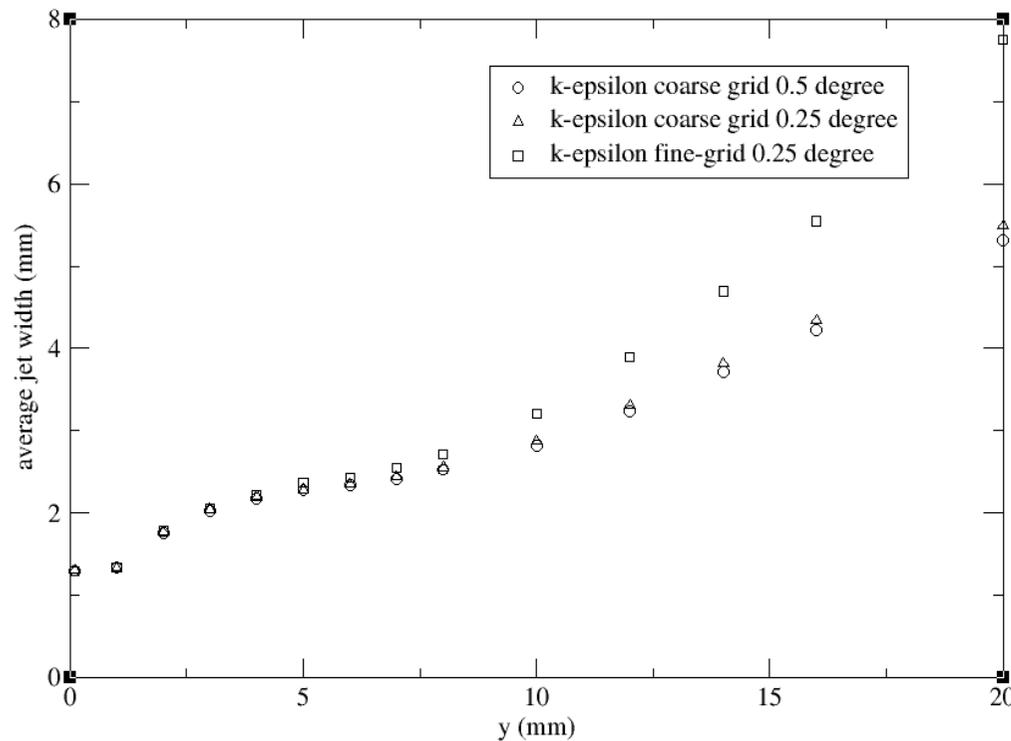
k - ε computations

- Computations are run until very-nearly-repeating periodic solutions are obtained (periodicity is satisfactorily achieved after about 10 cycles)
- Schemes:
 - Second order schemes (central differencing, Crank-Nicholson Adams-Bashforth)
 - ⇒ Robustness of the code
- Boundary conditions at the slot exit:

- $k=3/2 v^2$ and $\varepsilon=\frac{k^{3/2}}{L}$ with $L=1/2*\text{slot}$

k - ε computations

Average Jet Width



Case 1	Coarse grid	0.5 degree
Case 2	Coarse grid	0.25 degree
Case 3	Fine grid	0.25 degree

The width of the jet is sensitive to the grid refinement

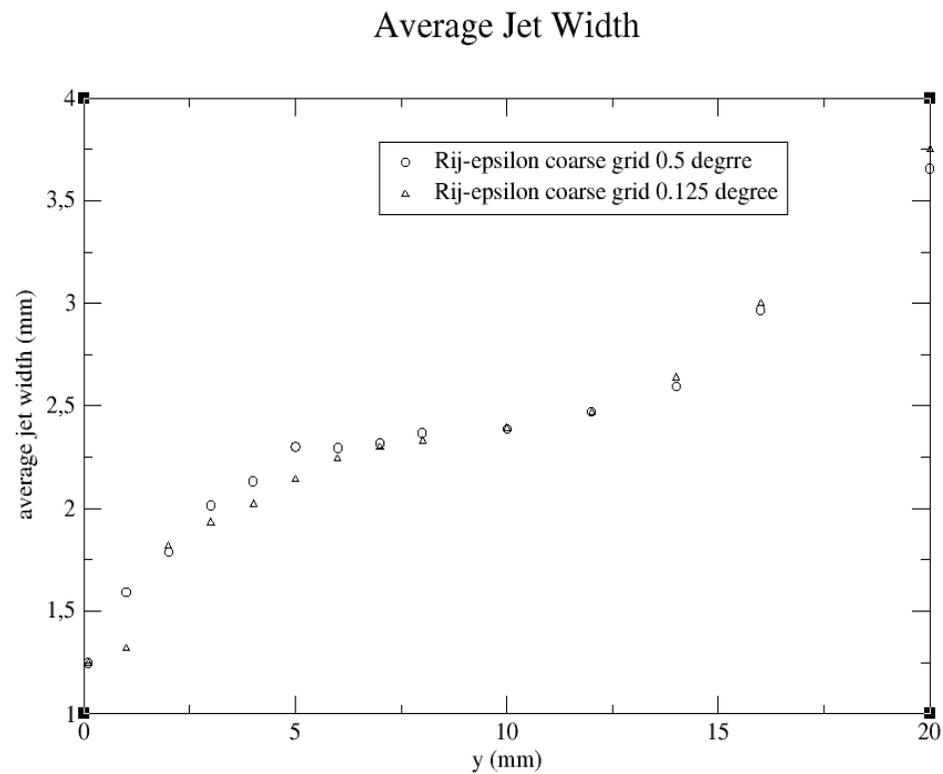
The reduction of the time step marginally influences the results

RSM computations

- The computations had to be started using upwind differencing and first order time marching
- They are restarted after 5 cycles with central differencing.
- No second-order time marching have been used, however, the time step was reduced in the last computation to limit numerical error.
- Boundary conditions at the slot exit

$$\langle u^2 \rangle = \langle v^2 \rangle = \langle w^2 \rangle \text{ and } \langle uv \rangle = 0$$

RSM computations



Conclusion

- The time step has no strong influence on the results
- The width of the jet is slightly sensitive to the grid refinement but the dynamics is by no means influenced
- The inlet conditions should be improved in order to be more realistic.
- The domain could be reduced
- A possible influence of the location of the outlets has to be determined